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Dissertation submitted in part fulfilment of the requirements for the Animal Husbandry section of the Degree of Master of Agricultural Science, University of New Zealand.

A. T. G. McArthur,

December, 1949

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INTRODUCTION.

The world shortage of food is the most serious crisis which faces mankind today. It is a crisis which has no earlier precedent and one for which remedial measures will be hard to find. The problem, first mentioned by Malthus in 1798, is one of limited food resources combined with an increasing world population. The basis of food production lies in the soil mantle of the world which is limited in extent and decreases yearly both in quantity and quality through the use of bad farming practices which lead to soil erosion.

The present level of human nutrition throughout the world is far from adequate. In North America and Australasia, the average daily consumption of calories per head is above 3000 but in the Middle East it is only 2400 while in the Far East it varies between 1700 and 2100, which is well below requirements (Fawcett (1948)). Not only are these people in need of more food energy but they also require more protein, minerals and vitamins. Livestock products are, of course, rich in these 'protective' foods and the expansion of livestock production will play an important part in raising the level of nutrition of the world's population.

Non-ruminant farm animals, pigs and poultry generally require food which can be used for direct human consumption - wheat, barley, maize etc. - so that it seems unlikely that they will be used to increase livestock production. However, the ruminant, because of its capacity to deal with fibrous food, is well adapted to utilizing grass. Grassland farming is often extensive as on the prairie, range or veldt, while in areas most suited to arable cropping, pasture may play only a secondary but nevertheless important part in returning the soil to a level of fertility suitable for further cropping through the judicious use of the legume and the grazing animal. However, where the climate is suitable for high pasture production, well spread throughout the year,

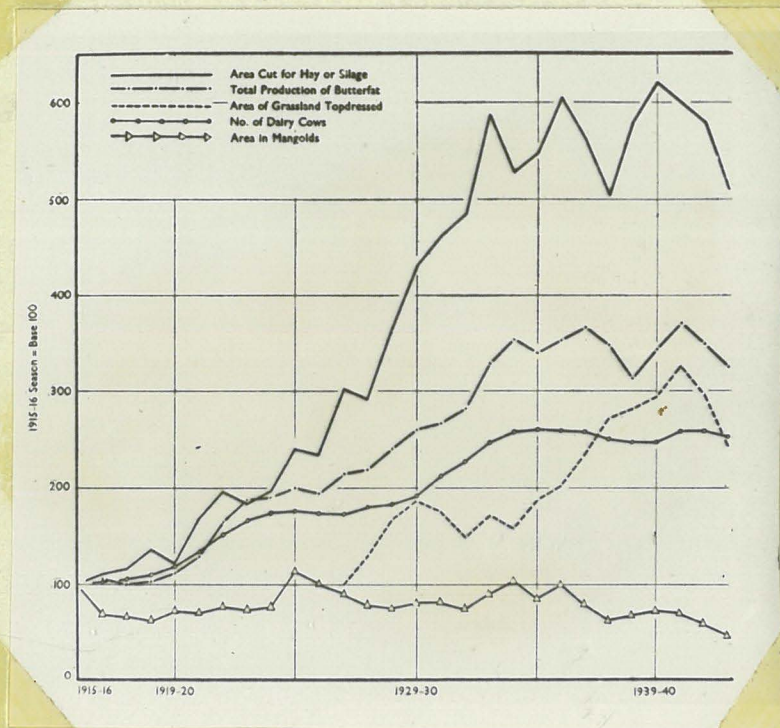


Figure 14. SHOWING THE RELATIONSHIP BETWEEN THE AREA MADE INTO HAY AND SILAGE, THE AREA USED FOR MANGOLDS, AND DAIRY PRODUCTION IN NEW ZEALAND.

So it is with New Zealand farming where grass, because of its predominant part in stock feeding, is treated as a crop capable of high production and improvable by cultivation, manuring and management. An important feature of this intensive grassland farming is the low labour requirement per unit of production, leading to low costs. From a study of the New Zealand dairy industry, Hamilton (1944) has shown that over the years the area of land used for growing mangolds has decreased while the area made into hay and silage has increased. (See Figure 14). The early dairy farmers grew root crops partly because they helped in preparing the land for sowing down grass, and partly because they clung to the traditional methods of the Old Country.

Although the climate in Great Britain is not as well suited generally for grassland production as that of the North Island of New Zealand, there is no doubt that pasture could be used more extensively for stock feeding, especially for dairy cows. Before World War II the production rations of dairy cows were based mainly on the use of cheap imported concentrates. Pasture and pasture products were mainly used for providing for maintenance requirements. Even though the work of Woodman (1926-32) and others showed that properly managed pasture had a high feeding value and could meet the requirement of high producing animals, no reliance was placed on it for milk production.

If more reliance was placed on grass as a food and if the methods of pasture establishment and management used by the New Zealand farmer were adopted by farmers in other countries, they too would obtain high production of livestock products from pasture.

The level of livestock production from intensively managed pasture depends upon:-

(a) the level of pasture production. Increasing pasture production is dependent upon the use of improved strains of grasses and clovers, judicious manuring and management.

(b) the efficiency with which pasture is utilized. Efficient pasture utilization involves the complete removal of grass from the paddock by grazing or cutting at a time when the quality of the pasture is most suited to the needs of the animal using it.

(c) the efficiency of the animal in turning grass feed consumed into the product required.

In this thesis, pasture utilization will be discussed in relation to New Zealand dairy farming. There is no evidence to show the magnitude of the losses of feed which occur through pasture utilization under dairy farming conditions. However the fact that not all the pasture food produced is actually consumed is illustrated below.

Various New Zealand workers have measured pasture production under a system of sheep rotational grazing with complete utilization. Elliot and Lynch (1943) have measured yield by using a grazing and cage technique simulating fairly closely practical farm conditions. During a good season (from Oct.1st 1940 to Oct.1st 1941) they obtained a yield of 11,787 lb of dry matter per acre in the Waikato, 4,734 lb of dry matter per acre at Stratford in Taranaki and 11,071 lb of dry matter per acre at Marton in the Rangeitiki plains. Hudson (1933) found yields of 4,638 lb to 8,806 lb at Marton using a mowing and grazing technique. Sears and Newbold (1942) obtained a yield of 13,700 lb of dry matter per acre on very extensively managed pasture at the Grassland Research station in the Manawatu. McMeekan (1947) estimates that the yield of dry matter per acre on a typical New Zealand sheep or dairy farm is between 6,000 and 8,000 lb.

However the butterfat production per acre for New Zealand dairy farms, which is determined by multiplying the number of cows milked by the average butterfat per cow and dividing by the area of the farm, is given in a report of survey work carried out by the Department of Agriculture for the Dairy Industry Commission (1934). A study was made of 550 high selected sample farms

on a district basis. The average figures were:-

Northland.. .. 93 lb	Auckland.. .. 144 lb
Taranaki 122 lb	Manawatu.. .. 132 lb.

Now theoretically 6,000 to 8,000 lb of dry matter should produce approximately 240 to 330 lb of butterfat which is well above the figures found in practice. The difference is by no means an accurate estimate of the loss which occurs through pasture utilization, for the average pasture production is merely a rough estimate and the output of butterfat per acre is difficult to calculate in practice. By using a method of measuring intake, it should be possible to measure pasture utilization losses under farm conditions, and such work is urgently required.

The general theme throughout this dissertation is the pasture utilization loss. As a fundamental background, pasture quality and grazing behaviour of dairy cows are discussed. The losses that occur through utilization by grazing are enumerated, and this is followed by a discussion of the factors which prohibit utilization and the solution of pasture utilization problems. The effect which pasture utilization has on production of pasture and the utilization of the grass feed consumed is considered.

Further experimentation in this field demands a knowledge of the intake of feed from pasture by the animal, and there is therefore a final section dealing with the methods which have been developed to measure intake.

The object of this work is to outline the subject of pasture utilization in relation to New Zealand dairy farming, illustrated by the evidence which is available. It is hoped that this dissertation will act as an impetus to further investigation.

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THE VARIATION IN FEEDING VALUE OF PASTURE.

To provide a background for this thesis, it is necessary to outline in brief the variations which occur in the feeding value of pasture. This discussion will be limited to the major constituents of grass - protein, nitrogen-free-extract, crude fibre, fat and ash. Details of the mineral content of pasture in New Zealand can be found elsewhere while such details as the biological value of the proteins, the vitamins and the hormones present in pasture are not considered relevant to the general theme.

While it is generally recognised that high-quality pasture is an adequate food for all classes of stock, it is surprising that grass has not been subject to more investigation when one considers that it is the most important single food used for farm animals.

Factors which influence the nutritive value of pasture.

The botanical composition of the sward plays an important role in determining the nutritive value of pasture. Williams and Davies (1932) in Wales have shown that clovers, in comparison with grasses, are high in crude protein and calcium while they have a lower crude fibre content. In New Zealand, Sears (1947) has found similar results. There is but little difference in chemical composition between grass species when compared at the same stage of growth under the same soil conditions (Fagan and Williams (1924)). Weeds, the other components of the sward, generally have a high protein and mineral content but are low in dry matter (Fagan and Walkins (1932)), (Milton (1933)), (Shapter (1935)). Although weeds are often palatable, especially during the winter, (Milton (1943)), they probably compare unfavourably with other pasture species in total production under high fertility conditions.

Broadly speaking, the nutrient content of a plant tends to be directly related to the level of nutrients in the soil (Richardson et al (1931)).

For instance, it is well known that the addition of nitrogenous fertilizers raises the protein content of grass (Fagan, Milton and Proven (1938)), while Sears (1947) has shown that high soil fertility gives pasture with a high nutritive value. The addition of phosphatic fertilizers to the soil raises the proportion of clover in the sward. The presence of clover itself improves the quality of the grass while added symbiotic nitrogen synthesis raises the nutritive value of the sward.

The stage of maturity at which the plant is utilized often overrides the effects which the botanical composition and the soil fertility play in determining the nutritive value of pasture. The rate of carbon assimilation of a plant is proportional to the leaf surface which increases up to the pre-flowering period. Again, the rate of uptake of nitrogen and minerals is most rapid in the early vegetative stages after which it decreases (Richardson et al. (1932)). As the plant matures, the nitrogen and mineral content decreases while there is an increase in structural tissue which leads to a lowered digestibility of all nutrients. This variation in pasture composition with stage of growth is related to the ratio of leaf to stem. Fagan and Jones (1924) have shown that the proportion of leaf to stem decreases with an increase in maturity. The leaf is richer in nitrogen and minerals than the stem. The crude fibre content is lower in the leaf and this leads to a higher digestibility of all nutrients.

Stapledon (1924), Woodman (1926, 1923, 1932, 1933) and Woodward (1939) show that as pasture matures the dry matter percentage increases but the digestible proteins, ash and fats diminish. Lowered digestibility of these nutrients is probably due to an increase of lignin content (Norman (1937)). Also the high content of readily digestible fructosan in immature herbage accounts for its high feeding value rather than its richness in protein.

If pasture is cut frequently in order to obtain grass of a high quality, the total yield of digestible nutrients will be depressed. Woodman's work

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showed that the longer the interval between cuts, the higher the yield of dry matter. A compromise between quality and quantity is made if the maximum yield of total digestible nutrients is required. Watson (1939) has recommended cutting pasture at an early stage in order to obtain ~~high~~ food with a high protein equivalent. But when a maintenance feed is required, early cutting may not be economical.

Theoretically a greater yield of nutrients can be obtained by rotational grazing. Under continuous grazing with efficient utilization the quality of the feed may be expected to be high but the total yield of nutrients will be depressed. Under rotational grazing the feed can be utilized when the quality is best suited for milk production so that the largest yield of total digestible nutrients will be obtained.

Sears and Goodall (1942) have shown that 8 - 10 inch spring pasture under high fertility conditions in New Zealand still has a protein content and digestibility comparable with the immature pasture studied by Woodman. It is unlikely that such long grass would have such a high feeding value during the summer or autumn and in any case such herbage would be difficult to utilize efficiently. One may conclude that the intervals between grazings should be as long as possible provided that the quality of the herbage does not fall below a level suitable for milk production. Also the pasture itself must not be too long or its utilization will be difficult.

Seasonal variations in pasture composition.

The seasonal variations in pasture composition depend on climatic factors such as the distribution of rain, but these are manifested mainly in changes in the stage of maturity of the pasture. Thus the proportion of leaf to stem is highest in the spring, lowest in the summer, rising again in the autumn (Fagan and Jones (1934)) and this leads to a lowering of the digestibility of nutrients during the summer, a depressed protein content and an increased percentage of fibre (Woodman (1926)). The extent of the depression

during the summer is modified by the botanical composition, for if there is in the sward a high percentage of clover which will make most of its growth during the summer, the depression of feeding value during the summer will not be so great.

Hudson (1933) at Marton, New Zealand, analysed pasture which was rotationally grazed by sheep. He found that the spring flush growth was characterised by a high protein content of approximately 34 per cent and a low fibre content percentage. During the summer the protein content was depressed (27 per cent), while the fibre content rose. The autumn growth had a higher protein content but the protein content of the winter pasture was low. Thus Hudson's work bears out the results of overseas workers.

We may conclude that botanical composition, soil fertility and stage of maturity all play a part in determining the composition of pasture. The quality of pasture varies throughout the year, being manifested in changes in the stage of maturity of the pasture plants. The quality is highest in the spring and autumn and lowest during the summer and winter.

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THE GRAZING HABITS OF DAIRY COWS.

The larger part of pasture output on dairy farms in New Zealand is utilized by grazing. Therefore it seems logical to make a study of the grazing behaviour of the animals that consume it.

Unfortunately, there is remarkably little knowledge readily available about the behaviour pattern of grazing animals, but some references to the relevant literature will be given below.

Ruminants have the ability to make use of more in the way of fibrous feeds than do other grazing animals, and furthermore, they are much less selective in their grazing habits than are non-ruminants. (See Beruldsen and Morgan (1938)). It is quite possible that the ability to take in feed rapidly and then to remasticate it later on is of some selective advantage in wild life.

A general survey of the behaviour of the grazing animal should help to throw some light on many of the pasture and animal management problems with which the farmer is vitally concerned.

Thus James Anderson (1797), a Scots farmer, after making some observations on the grazing behaviour of his fattening beasts, decided to adopt a system of rotational grazing. He noticed that his stock appeared to relish fresh clean feed, and also that they thrived on it, and he therefore adopted the system which today we consider an efficient

method of pasture utilization.

The grazing pattern of a cow appears to be governed by its genetical make-up, its feed requirements, the climate, and the pasture environment. Before the limited data on these factors is discussed, a picture will be given of the normal habits of dairy cows.

Johnstone-Wallace (1944) discussed the foraging habits of beef cattle and states that "the mechanical process of grazing involves the severing of the leaves and stems of grasses, legumes and weeds with the two jaws of the animal measuring on an average, about $2\frac{1}{2}$ inches across, and having one row of teeth in the front on the lower jaw. A muscular pad on the upper jaw presses against these teeth and enables the tearing action to take place... The tongue is in constant action during grazing usually being protruded with great rapidity, alternately from either side of the mouth. Its function appears to be to simplify the collecting process, as well as the swallowing process. The head of the cow moves from side to side as she moves forward, the neck being flexed within an arc of about 90 degrees".

Undershot jaw may prevent a cow from collecting sufficient food to meet its requirements, especially under poor conditions. Hancock (1948) quotes the case of a set of twins at Ruskura. One gave 350lb of butterfat on adequate pasture supplemented with concentrates while the other only gave 100lb of butterfat on an area of pasture which was 40% smaller. However this difference was very much greater than the average treatment differences. The reason was that both had an undershot jaw but the latter was unable to forage efficiently under poorer conditions.

Hancock and Wallace (1947) at Ruskura, New Zealand, find that the average number of bites per day for four cows that they observed is 23,500. The average number of bites per minute is 51. If it is assumed that the cows consumed 150 lb of green grass per day, then each bite weighs about one tenth of an ounce. As a cow takes in such small quantities at once it can be appreciated

that potentially she is a very selective animal. Selectivity will be dealt with later.

The same workers observed the grazing behaviour of six sets of monozygotic twins (first calvers) for six twenty-four hour periods at monthly intervals through the main lactation season. 7 hours in each 24 were spent in grazing, while 10 were spent in lying down. The remainder of the day was spent loafing, i.e. standing and walking around but not grazing. Similar results have been found by Southcombe (1947) from observations of the dairy herds at Massey College. The most obvious feature of the behaviour pattern is its cyclic nature. Southcombe observed three regular grazing periods during the day and two at night. A similar pattern was noticed by Corbett (1949) from his 24 hour watch on calves. Observations by the present writer (1948) showed how the whole herd tended to act as a unit and also that the intensity of grazing, as measured by the bites taken per minute, decreased during each grazing period.

It was believed by Cory (1927) and Ellingboe (1924) that no grazing takes place at night, but Hancock and Wallace (1947) found that 42 per cent of the grazing took place between 5 p.m. and 4.45 a.m. and 58 per cent between 7 a.m. and 3 p.m.

However, comparatively little grazing is done between midnight and milking time (Levy 1935). Southcombe (1947) has confirmed these results.

The Ruakura workers measured the distance their twins walked, finding it to be approximately 2 miles. Similar distances were found by Johnstone-Wallace and Kennedy (1944) in America, and Anon, (1948) at the Grassland Improvement Station, England, with beef cattle.

These English workers find that nearly 9 hours are spent in cudding.

One observation for a 24 hour period by the American workers showed a cudding time of 7 hours. Hancock (1948) states that the twins he has studied usually spend about three quarters of the time they take to graze in cudding. However,

Southcombe (1947) states that the times devoted to chewing the cud show much variation. His observations did not take account of cudging either in the yard or in the night paddocks. It was noticed, nevertheless, that when a cow began ruminating, she persisted for some 15--20 minutes, before abruptly stopping. This feature has been noted by Corbett (1949) in calves.

Johnstone- Wallace and Kennedy (1944) found that the average number of defecations and urinations made by beef cows on pasture was 8.5 and 12.75 respectively. Hancock (1948) states that of the total time spent in grazing, 60 per cent of the manure falls between the morning and the afternoon milking, and the remainder, or 40% (per cent) between the afternoon and morning milking. It is widely held that more stock manure falls at night than during the day. This has been clearly proved in the case of sheep (Davies (1937)) and it was generally accepted that the same held good for dairy cows -- hence the build-up of fertility in night paddocks. However, Hancock believes this to be due to their comparatively small size giving them a larger shower of manure per acre than the day paddocks.

This work requires confirmation in terms of actual weights.

Having obtained a picture of the grazing pattern of dairy cows, it is now necessary to discuss the limited information concerning the variations that occur and the factors which cause them.

Hancock and Wallace (1947) found that the identical twin heifers they studied spent from 26 to 32 percent of their time grazing but that the pattern of grazing was strikingly similar within sets of twins. Thus the "within sets of twins" intra-class correlation was 0.9038 for grazing. However, the correlation for time spent loafing and lying down was negligible.

The grazing pattern appears therefore to be determined to a considerable extent by the genotype of the animal concerned.

In consequence, one might expect to find some differences between breeds in grazing behaviour. Indeed Southcombe found that Jerseys grazed for a longer

time than Friesians, especially during the night and they also walked further. As he found that the rate of eating, as measured by the bites taken per minute, was similar in both breeds, he concluded that the Jersey must be a more selective grazer. These facts probably show that the Jersey takes in less feed per mouthful but this does not necessarily make her more selective.

A low correlation has been found between the theoretical T.D.N.requirements and the grazing time (Hancock and Wallace (1947)). Now if there is a strong relationship between the amount of food consumed and the grazing time-- this has yet to be shown but would seem probable --, then the low producing cows in the herd consume a larger amount of feed than they require to meet production and maintenance requirements. This reveals a possible weakness connected with free-grazing conditions, for unless the requirements of the cow play a large part in determining the intake from pasture, the low producers consume more than their share.

Seasonal and climatic conditions may affect the grazing pattern. Southcombe (1947) found a definite trend towards shorter grazing hours during the Winter. Hancock (1948) reports that cows walked further on cold and blustery or extremely warm days and emphasized the need for adequate shelter on pasture.

Seath and Miller (1946) studied the effect of warm weather on the grazing performance of three Jersey and three Holstein cows in Louisiana. They found that high day temperatures decreased the portion of the time spent grazing during the day and increased night grazing. Thus on the warmest days 23 per cent of the grazing was done during the day while on cooler days the daytime grazing increased to 44 per cent. The day temperatures are lower in New Zealand and both Southcombe and Hancock have found that about 60 per cent of the grazing takes place during the day. Climatic conditions seem to alter the grazing pattern considerably.

The condition of the pasture may also affect the changes in grazing

behaviour. Hodson (1933) compared the grazing pattern of Holsteins grazed continuously and rotationally. He found that less time was spent foraging under rotational grazing conditions but that grazing time increased after the cows had been on a paddock for some days. Although his data was scanty and he only made observations during daylight hours, he concluded that less energy is expended by cows under rotational grazing. His results are supported by Shepperd's (1921) observation that the larger the paddock the further the animal travels.

Atkeson et al. (1942) found that although cows on poor pasture received supplementary food they were forced by the sparse condition of the herbage to graze for a longer time than on good paddocks. Hancock (1948) states that cows will put in up to 10 hours grazing in a day on scanty pasture which is contrary to the conclusion reached by Johnstone-Wallace and Kennedy (1944), who maintained that cows have not the capacity to graze more than seven hours.

It is obvious that there is a limit to the number of hours a cow ^{can} put in. Hancock (1948) states that a hard working cow could put in 10 hours grazing, 9 hours rumination, 3 hours off the paddock being milked and 2 hours complete rest, which appears to be their minimum requirement.

A cow that has to eat for a long time may be so enforced to reduce her cudging time, utilizing her food poorly.

As a conclusion, Hammond (1944) may be quoted;---

" The study of animal behaviour should have a great influence in making a science of what was now known as the stockman's art. A good stockman was one who knew exactly what his animal wanted and how it was feeling. The development of a science for this subject would be of great use to animal husbandry"

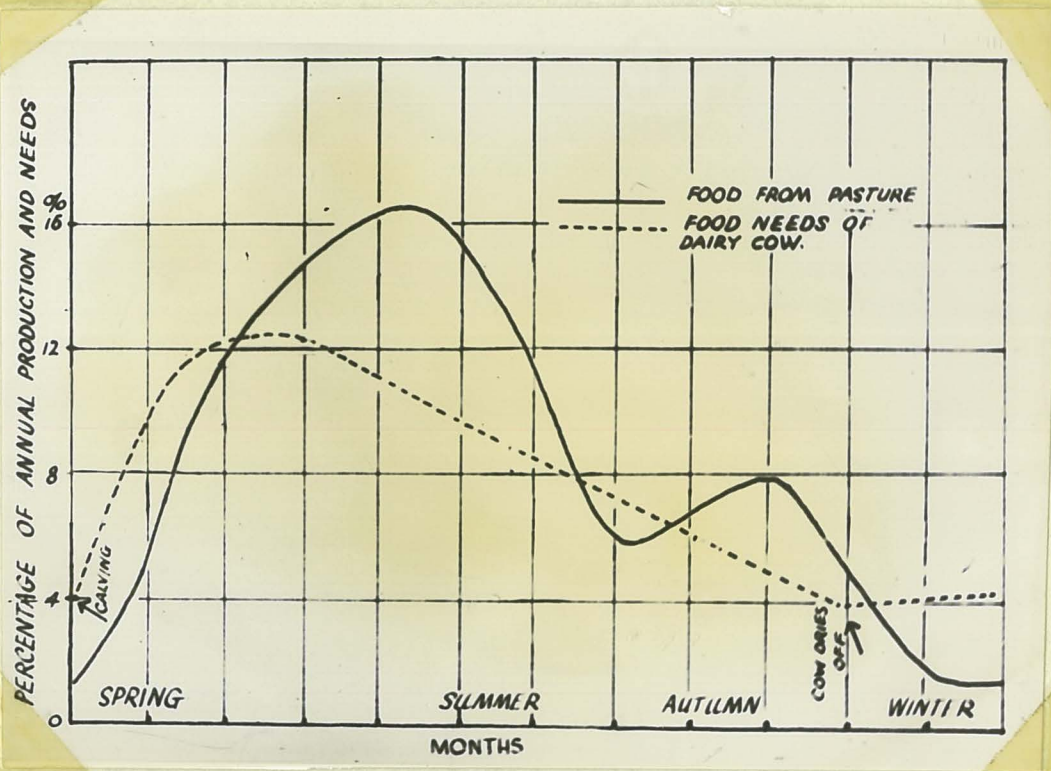


Figure 1. A DIAGRAM SHOWING THE RELATIONSHIP BETWEEN THE REQUIREMENTS OF A DAIRY COW AND PASTURE PRODUCTION.